§11. Superconducting Current Feeder System for the LHD

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We decided to use an SC current feeder system for the LHD after considering the following points. The merits of using SC busline are: 1) reduction of the capacity of the power supply system, 2) simplification of the busline assembly works on site, and space saving around the main device. In the case of LHD, the electrical power comsumption exceeds 1.5 MW.

Figure 1 shows a bird-eye's view of the SC current feeder system for LHD. A total number of nine SC buslines is necessary, six for the helical coils and three for the poloidal coils. The operating current of the helical coil at phase 2 experiments is 17.3 kA. The operating currents of poloidal coils IV, IS and OV are 20.8 kA, 21.6 kA and 31.3 kA, respectively. The distance between the SC coils and their current-leads is 45.8 - 59.0 m. The routes of the SC buslines are designed to have no sharp bends.

The coolants of the SC busline are separated from that of the SC coil system. The SC current feeder system should be able to maintain its rated capacities for 30 minutes, if the coolant flow is accidentally stopped. The heat balance between the heat inputs and cooling capacities has been investigated. According to scaling laws, the actual current leads are designed to sustain liquid helium for 30 minutes. The total heat input in the SC busline is estimated to be 65 W. It can be canceled by evaporating 50 L of liquid helium within 30 minutes. The current feeder system is designed to have liquid helium reservers for the self-cooling.

The design specifications for the SC buslines are listed in table 1. An aluminium-stabilized, SC-compacted stranded cable was specially developed to satisfy the high stability and flexibility requirements of the SC busline. Electrical insulation was inserted between a pair of + /- cables. The temperature rise of the SC cable is calculated to be less than 50 K when the current decays from 30 kA to zero with a time constant of 20 sec under adiabatic condition [1]. Breakdown voltage between + /- cables was measured with test pieces of actual SC cables 150 mm in length. Both ends of the test pieces were covered with electrical insulation. Tests were conducted over a wide range of temperatures from 4.2 K to 294 K using helium gas. The test results are listed in Table 2. In the coil protection circuits of the actual LHD, maximum induced voltage of the coils is 1.9 kV when de-excitation is rapid and the decay time constant is 20 sec. As shown in Table 2, the insulation structure of the SC cables has a large withstanding voltage margin [2].

Table 1. Specifications of SC busline for LHD.

Items	Specifications
Number of SC busline	6 (for helical coils) 3 (for poloidal coils)
Rated current	32 kA
Rated withstanding voltage	5.7 kV (in 80 K gas helium)
Minimum bending radius	1.5 m
Length of SC bus line	45 - 65 m
Heat load into SC bus-line	0.3 W/m (from 80 to 4.2 K) 3 W/m (from 300 to 80 K)
Type of cryogenic tubes	five corrugated tubes (with thermal shield)

Table 2. Measured breakdown voltages of the short samples.

Conditions	Breakdown voltages
liquid helium	more than 20 kV
6 - 40 K helium gas	more than 20 kV
75 - 80 K helium gas	8.33 kV
280 - 294 helium gas	3.21 kV

References

1. T. Mito, S. Yamada et al, 1994 Applied Superconductivety Conf., 16-21 Oct., 1994, Boston, LQC-2.
2. S. Yamada, T. Mito et al, 14th Magnet Technology, 11-16 June, 1995, Tampere, B-72.

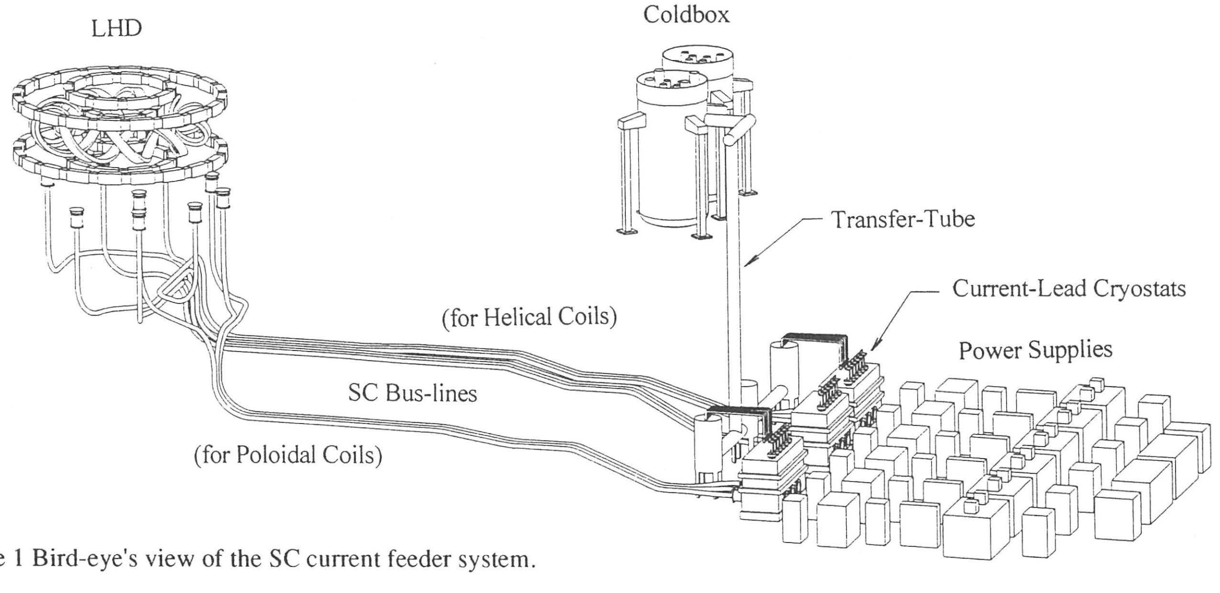

Figure 1 Bird-eye's view of the SC current feeder system.